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Original Article

Very early screening for sleep-disordered breathing in acute coronary syndrome in patients without acute heart failure

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ABSTRACT

Background: Obstructive sleep apnea (OSA) is frequently associated with acute coronary syndrome (ACS). Screening of sleep-disordered breathing (SDB) has not been previously evaluated in ACS within 72 h in intensive care settings and its management could potentially enhance patients' prognosis. This pilot study assessed the feasibility of SDB screening at the early phase of ACS.
Methods: All consecutive patients admitted to the coronary care unit (CCU) for ACS without acute heart failure underwent one overnight-attended polysomnography (PSG) within 72 h after admission. A telemonitoring (TM) system was set up to remotely monitor the signals and repair faulty sensors. The 27 recordings were analyzed as respiratory polygraphy (RP) and as PSG, and the results were compared.
Results: The TM system allowed successful intervention in 48% of recordings, resulting in excellent quality PSG for 89% of cases. The prevalence of SDB [apnea–hypopnea index (AHI) ≥ 15/h] was 82% and mainly consisted of central SDB and periodic breathing, except three patients with OSA. Compared with PSG, RP underestimated AHI, probably due to the poor sleep efficiency, reduction of slow-wave sleep, and alteration of rapid eye movement sleep.
Conclusion: An early SDB screening by remote-attended PSG is feasible in ACS patients shortly after admission to CCU. The TM enhanced the quality of PSG. A high prevalence of central SDB was noticed, for which the etiology remains unknown. Further large-scale studies are needed to determine whether central SDB is an incidental finding in early ACS and whether the presence and severity of SDB have a prognostic impact.

1. Introduction

There is a close, reciprocal relationship between ischemic heart disease and sleep-disordered breathing (SDB) [1,2]. A high prevalence of obstructive sleep apnea syndrome (OSA) (from 43% to 66%) has been reported in the early phase of acute coronary syndrome (ACS) [3]. OSA increases the risk of a new coronary event after ACS [4,5]. Systematic screening for SDB at the acute phase of ACS is not recommended, as some studies have demonstrated that the prevalence of OSA tends to decrease over time after the initial event [6–8]. However, very early SDB screening within 72 h of ACS in intensive care settings has not been performed yet by attended polysomnography (PSG). Considerable progress has been made in the medical management of ACS with very early reperfusion therapy. However, despite optimization of medical management, mortality remains high in patients with comorbidities, particularly in patients with SDB [9]. Early detection and management of SDB could therefore potentially help decrease the morbidity and mortality of ACS [10,11]. Screening rather than case-finding based on patients' symptoms could be more appropriate in this specific population that does not complain from excessive daytime sleepiness [12,13]. This pilot study evaluated the feasibility of early SDB screening in a homogeneous population of patients without acute heart failure (HF) admitted to a coronary care unit (CCU) for ACS. The accuracy of two diagnostic procedures, PSG and respiratory polygraphy (RP), was

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compared, based on the assumption that the ideal screening tool remains controversial. As an early SDB diagnostic strategy in CCU implies an additional workload for the nursing team and is associated with a high risk of failure, a telemonitoring (TM) system was used for real-time monitoring of sleep recordings during the night.

2. Methods

2.1. Study design and patient population

This was a prospective observational study. Sleep recordings were performed on a convenience sample of consecutive patients with ACS admitted to the Groupe Hospitalier Pitié-Salpêtrière Coronary Care Unit (CCU) between September 2012 and December 2012, regardless of the presence of symptoms of excessive daytime sleepiness. Inclusion criteria were: aged ≥ 18 years, ACS defined by ischemic symptoms and electrocardiogram (ECG) repolarization abnormalities together with either serum troponin elevation above the upper limit of normal and/or significant coronary artery stenosis (≥70%). Patients with stable cardiac condition either with ST-elevation ACS or non-ST-elevation ACS were included. Patients with known SDB, hemodynamic instability, clinical acute HF (dyspnea, orthopnea or inspiratory crackles) or who were unable to provide their informed consent were excluded. The protocol was approved by the local research ethics committee "CPP Ile de France VI Pitié Salpêtrière" (file no. 71–12). All subjects provided their written informed consent.

2.2. Patient assessment

Clinical examination was performed and demographic characteristics, echocardiographic, and angiographic data were collected before PSG. Subjective daytime sleepiness was assessed by the Epworth Sleepiness Scale (ESS).

2.3. Respiratory polygraphy and polysomnography recordings

All patients underwent one overnight real-time remotely attended sleep test in their own room in the CCU. Sensor placement was performed by the same trained sleep physician at about 07:00, and the monitor was removed by the same physician the next morning (08:00). A battery-operated portable polysomnograph (Dream®, Medatec, Brussels, Belgium) was used to record chest and abdominal movements, airflow, pulse oximetry (Nonin®, Minneapolis, MN, USA), 5-channel electroencephalogram (EEG), two electrooculograms, submental electromyogram, anterior tibialis electromyogram, and ECG. A microphone recorded tracheal sounds and body position was assessed using a built-in position sensor (mercury gauge) with four different levels.

2.4. Telemonitoring (Fig. 1)

The Sleepbox® (Medatec) is a TM system allowing real-time remote PSG visualization from the sleep laboratory, previously assessed in a feasibility study [14]. The Sleepbox was placed in the patient's room. CCU nurses were carefully trained about the various parameters recorded and correct sensor placement so that they could replace sensors whenever necessary. The sleep laboratory was located in a different building from the CCU. The sleep laboratory nurse performed continuous remote monitoring of the recording during the night. When a defective oximetry, nasal pressure, or ground electrode signal was observed or when fewer than two EEG recordings became readable, the sleep laboratory nurse contacted the CCU nurse by phone to ask her to replace the faulty electrodes.

2.5. Scoring and analysis of sleep studies

PSG recordings were interpreted independently by two sleep physicians: the first physician analyzed only respiratory parameters and the second physician, blinded to the respiratory results, analyzed the PSG. Manual scoring of PSG was performed according to American Academy of Sleep Medicine guidelines [15].

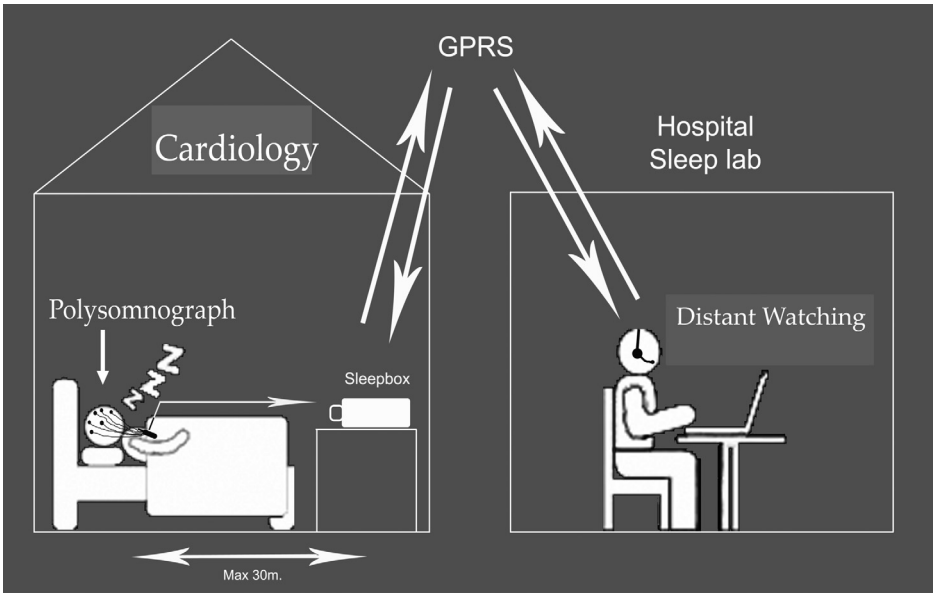

Fig. 1. Polysomnographic (PSG) telemonitoring protocol. The Sleepbox® is a telemonitoring system, using an internet communication (GPRS), allowing real-time remote PSG visualization from the sleep laboratory located in a different building from the coronary care unit (CCU). The sleep laboratory nurse performed continuous remote monitoring of the recording during the night. In case of defective signal, the sleep laboratory nurse contacted the CCU nurse by phone to ask her to replace the faulty electrodes.

Respiratory events are expressed as apnea–hypopnea index (AHI), which is the mean number of events per hour of sleep for the polysomnography (AHI-PSG) and per hour of recording for the polygraphy (AHI-RP). An AHI ≥ 15/h (sleep or recording time) was considered as significant. An obstructive apnea was defined as the absence of airflow (<10% of the surrounding baseline) for ≥10 s, in the presence of rib cage and abdominal effort. Central apnea was defined as the absence of airflow (<10% of the surrounding baseline) for ≥10 s with absence of rib cage and abdominal effort. Mixed apnea was defined as a succession of obstructive and central apneas. Hypopnea was defined as a 50% decrease in airflow or thoraco-abdominal movement, for ≥10 s, or a smaller decrease, accompanied by oxygen desaturation ≥ 3% or/and by an arousal. OSA diagnosis was defined as ≥50% obstructive apneas and hypopneas of all apneas and hypopneas. Central sleep apnea syndrome (CSAS) diagnosis was defined as ≥50% central apneas and hypopneas of all apneas and hypopneas [16]. Periodic breathing (PB) or Cheyne–Stokes respiration (CSR) episode was defined as at least three cycles of crescendo then decrescendo of the ventilation, followed by central apnea or hypopnea [17]. Arousals are expressed as the mean number of occurrences per hour of sleep (ArI). The quality of RP and PSG recordings was graded according to the classification of Redline et al. [18].

2.6. Patient treatment and follow-up

All patients were informed of the results of their sleep study during their hospitalization.

2.6.1. Treatment

In cases of severe OSA, treatment by continuous positive airway pressure (CPAP) was set up immediately after the SDB diagnosis and a sleep physician followed them. In cases of CSAS, the cardiologist optimized the cardiac treatment to improve the cardiac function and additional adaptive servo-ventilation (ASV) was offered if required [19].

2.6.2. Follow-up

Follow-up was strongly suggested due to the potential clinical implication, but was not mandatory according to the study design. For central SDB patients, we proposed to perform a free second RP at home around 15 days after the ACS. We also suggested to all SDB patients that they return to the sleep laboratory six months after the initial evaluation for a second PSG, in order to evaluate the persistence of SDB.

2.7. Statistical analysis

Descriptive statistics are reported as median and interquartile range (IQR) for quantitative variables and as frequency (%) for qualitative variables. The method described by Bland and Altman was used to analyze the agreement (AHI obtained) between RP and PSG. The mean value for measurements obtained with the two methods was plotted on the *x*-axis. The difference between the two values was plotted on the *y*-axis. The bias was estimated by the mean difference, with a two-sided 95% confidence interval for the theoretical mean. Points situated below zero indicate that AHI-RP was higher than AHI-PSG, whereas points situated above zero indicate that AHI-PSG is higher than AHI-RP (underestimation of AHI by RP). The association between gender or presence/absence of SDB and cardiovascular risk factors was assessed using Fisher's exact test. The correlation between left ventricular ejection fraction (LVEF) impairment and the severity of CSAS was evaluated by Pearson's correlation coefficient.

Table 1
Patients' demographic and clinical characteristics.

Characteristics	Median (IQR) or no. (%)
No.	27
Age (years)	59 (19)
Male	22 (81%)
Cardiovascular risk factors	
Hypertension	14 (52%)
Diabetes mellitus type 2	9 (33%)
Obesity (BMI ≥ 30 kg/m^2)	4 (15%)
Hypercholesterolemia	18 (67%)
Current or ex-smokers	17 (63%)
Active smokers	11 (41%)
Smoking pack-years	20 (20)
Physical examination	
BMI (kg/m^2)	24 (3)
Neck circumference (cm)	39 (5)
Systolic blood pressure (mmHg)	109 (23)
Diastolic blood pressure (mmHg)	65 (15)
Heart rate (beats/min)	74 (14)
Daytime SpO_2 (%)	97 (2)
New York Heart Association class	2 (1)
I	9 (33%)
II	16 (60%)
III	2 (7%)

IQR, interquartile range; BMI, body mass index; SpO_2, oxygen saturation.

3. Results

3.1. Baseline and clinical characteristics

Twenty-nine consecutive patients admitted to the CCU for ACS between September and December 2012 were asked to participate in the study. Two patients refused because they were afraid of the procedure. A complete sleep study was performed in 27 patients, 14 (52%) with ST-elevation ACS, and 13 (48%) with non-ST-elevation ACS. PSG was performed very early after admission (median of two days). PSG was recorded during the first 48 hours of admission in 18 patients (67%). The majority of the study population did not complain of excessive daytime sleepiness [median ESS of 6; three patients had ESS ≥ 11]. The patients' demographic and clinical characteristics are presented in Table 1. There was no statistically significant difference between males and females regarding the distribution of cardiovascular risk factors (hypertension, diabetes mellitus, BMI ≥ 30 kg/m^2, hypercholesterolemia, tobacco). Similarly, no significant correlation between the presence of SDB and the number of cardiovascular risk factors was found. Cardiological data are shown in Table 2. The median LVEF was 50%. Among the CSAS and mixed patients with a preserved ventricular function ($n = 16$) (median LVEF, 50%), there were 81% men with a median age of 63 years and a median BMI of 25 kg/m^2. These patients presented globally severe CSAS (median AHI, 40/h), inducing highly fragmented sleep (ArI, 35/h). Only three patients presented LVEF < 40%: their

Table 2
Cardiological data.

Variables	Median (IQR) or no. (%)
Cardiac ultrasound data ($n = 26$)	
LVEF (%)	50 (4)
No. of patients with LVEF < 40%	3 (11%); mean LEVF 30%
Pulmonary arterial hypertension	0
Coronary angiographic data ($n = 27$)	
No. of coronary arteries with significant stenosis:	
None	2 (7%)
1-vessel disease	11 (41%)
2-vessel disease	5 (19%)
3-vessel disease	9 (33%)

IQR, interquartile range; LVEF, left ventricular ejection fraction.

Table 3
Polysomnography and respiratory polygraphy data ($n = 27$).

Variables	PSG analysis	RP analysis
	Median (IQR) or *n* (%)	Median (IQR) or no. (%)
AHI	39 (38)	17 (23)
AHI < 15/h	5 (18%)	10 (37%)
AHI ≥ 15/h	22 (82%)	17 (63%)
Obstructive pattern	3	3
Mixed pattern	1	1
CSAS and PB	18	13
AHI ≥ 30/h	18 (67%)	12 (44%)
Mean SpO_2 (%)	92 (3)	94 (3)
% Time < 90% SpO_2	1 (6)	1 (6)
SpO_2 min (%)	83 (30)	83 (30)
ODI (/h sleep)	17.5 (31)	NA
TIB (min)	780 (61)	NA
Sleep efficiency (%)	61 (14)	NA
Sleep cycle/night (no.)	3 (3)	NA
TST (min)	386 (143)	NA
Sleep latency (min)	142 (115)	NA
Arousal index	37 (23)	NA
Stage N1		
%/TST	7 (6)	NA
Duration (min)	21 (24)	NA
Stage N2		
%/TST	47 (24)	NA
Duration (min)	145 (111)	NA
Stage N3 (SWS)		
%/TST	34 (27)	NA
Duration (min)	100 (120)	NA
REM sleep		
%/TST	9 (10)	NA
Duration (min)	26 (46)	NA

PSG, polysomnography; RP, respiratory polygraphy; IQR, interquartile range; AHI, apnea–hypopnea index; CSAS, central sleep apnea syndrome; PB, periodic breathing; SpO_2, oxygen saturation; ODI, oxygen desaturation index; TIB, time in bed; NA, not assessed; TST, total sleep time; SWS, slow wave sleep.

mean LVEF was 30% without clinical or echographic signs of acute HF. These three non-obese patients (two males and one female, median age of 82 years) suffered also from severe CSAS (median AHI, 49/h).

All the patients received optimal cardiac management [20] during hospitalization, 23 patients (85%) received beta-blockers, 21 (78%) received angiotensin-converting enzyme inhibitors, 21 (78%) received an antiplatelet drug, three patients received an angiotensin II receptor blocker, three received spironolactone, and seven received a loop diuretic. All patients received statin, aspirin, and one anticoagulant drug. No opioids were administered to any of the patients, whereas six patients occasionally received benzodiazepines.

3.2. Quality of polysomnography and telemonitoring

All recordings were interpretable (100% success rate). The quality of PSG recordings was scored as excellent in 89% of cases (24/27). The other three PSG recordings were scored as very good ($n = 1$), good ($n = 1$), and fair ($n = 1$). The quality of RP recordings was scored as excellent in 96% of cases and good in 4% of cases, according to the same classification adapted to RP. Remote surveillance was efficient in 78% of patients ($n = 21/27$) and 10 interventions were performed, eight for replacement of nasal cannula, one for electrode repositioning, and one for pulse oximeter. The median interval between remote detection and the corresponding intervention was 11 min.

3.3. Polysomnography and respiratory polygraphy results

Patients spent a long time in bed, mostly in the supine position. Sleep efficiency (SE) was globally reduced and a high arousal index was observed in all patients (Table 3). More heterogeneous results were observed for other sleep parameters. Total sleep time (TST) was in the normal range for 15 patients and reduced in 12 patients (44%). Wide range of slow-wave sleep (SWS) duration varied considerably between patients. Five patients presented a marked reduction or absence of SWS, whereas five patients had a normal SWS duration and 17 patients presented a rebound representing up to 69% of TST. Rapid eye movement (REM) sleep time was normal in four patients, reduced in 20 patients, and REM sleep was absent in three patients. Using an AHI cut-off of 15/h, a high prevalence of SDB was observed (82% on PSG). Only three patients suffered from OSA, severe in all cases: two men (AHI-PSG respectively 46.8 and 57.6/h) and one woman (AHI-PSG 31/h). In contrast, there was a high prevalence of central SDB including Cheyne–Stokes respiration (CSR) (Fig. 2) and 24% of patients exhibited CSR while awake (Table 4). All of the CSAS-PB and mixed patients presented 90% of non-REM (NREM) sleep, including 26% of SWS, and 10% REM sleep. Our three OSA patients exhibited 85% of NREM sleep, including 21% of SWS, and 15% REM sleep. In CSAS patients, there was no statistical evidence for a significant association between the AHI and LVEF values: the Pearson correlation coefficient reached 0.15 (95% CI, –0.35 to 0.59) ($P = 0.55$).

Periodic breathing (PB) induced marked sleep fragmentation. Compared to PSG, RP tended to underestimate AHI for patients with CSAS and PB (Fig. 3), and PSG and RP showed similar results in OSA patients. On the Bland–Altman analysis (Fig. 4), there was a bias (mean difference) of 19.85 (standard deviation 21.38) for the AHI with a two-sided 95% CI (–22.06 to 61.76). This suggests that RP underestimates the AHI with a bias of almost 20 compared to PSG.

3.4. Follow-up

3.4.1. Second RP 15 days after discharge in central sleep apnea syndrome patients

Five CSAS patients were reassessed by a second RP. Even if the results might suggest a tendency toward SDB regression, one out of five patients still presented AHI-RP ≥ 30/h, four out of five patients AHI-RP ≥ 15/h, and three out of five still presented CSAS and PB 15 days after discharge.

3.4.2. PSG reassessment at six months in sleep-disordered breathing patients

Four patients were reassessed. Among OSA patients ($n = 3$), all treated with CPAP, two were reassessed after six months by PSG. CPAP therapy had been interrupted for 10 days before the sleep recording. There was a slight reduction in AHI-PSG from 46.8 to 28.7/h and from 57.6 to 42.4/h, respectively. Among CSAS and mixed patients ($n = 19$), two CSAS patients were re-evaluated. Remission of CSAS and PB was observed in one patient (LEVF 40%): AHI from 73.7 to 8.4/h. The second patient (LEVF 50%) still presented severe CSAS and PB: AHI 79.3–75.3/h, such that treatment with ASV was initiated.

Among the seven CSAS patients reassessed (after 15 days or six months), five patients clearly improved although some PB persisted and two patients exhibited severe CSAS. These two severe patients presented an unstable cardiac condition, as the first died from a new ACS and the second was treated with ASV.

4. Discussion

To our knowledge, this is the first study to demonstrate the feasibility of very early SDB screening in ACS patients admitted to a CCU. Another strength of this study is the performance of remote-attended recordings and comparison of the accuracy of RP and PSG at the early phase of ACS. An unexpectedly high prevalence of central abnormalities was observed in this population of patients without acute HF.

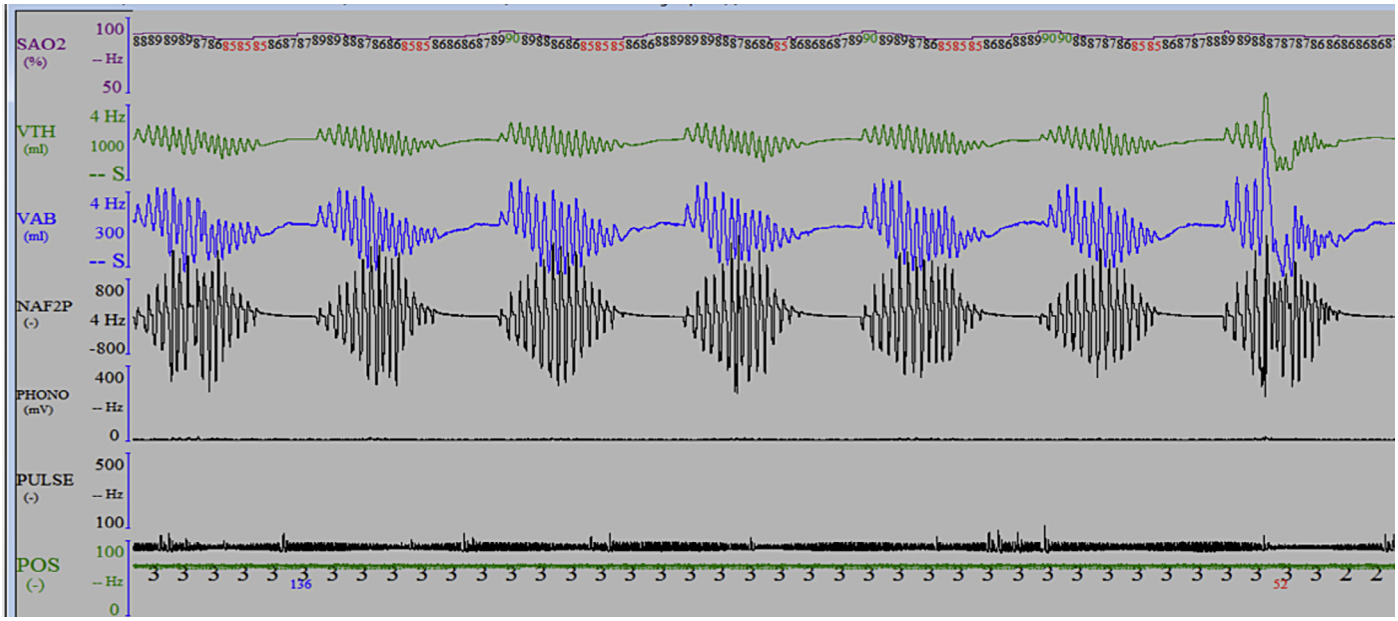

Fig. 2. Example of Cheyne–Stokes respiration and periodic breathing in one patient. A high prevalence of central sleep apneas including Cheyne–Stokes respiration was observed in our population (82% of our SDB patients). SAO_2, oxygen saturation; VTH, thoracic belt; VAB, abdominal belt; NAF2P, nasal airflow; PHONO, microphone recording tracheal sound; PULSE, pulse wave amplitude; POS, body position; 3, stage N3 sleep (SWS).

Table 4
Periodic breathing

No = 27	Median (IQR†) *or* n (%)
Presence (No patients)	22 (82%)
Number of episodes/patient (*n*)	9 (7)
$N = 0$	3 (11%)
$1 \le N < 5$	10 (27%)
$5 \le N < 10$	4 (15%)
$N \ge 10$	13 (48%)
During sleep only (*n*)	17 (71%)
During weakfulness + sleep (*n*)	7 (24%)
Mean duration/patient (min)	48 (132)
Minimal duration/episode (min)	2 (3)
Maximal duration/episode (min)	24 (22)
% TST*/patient	17 (64)

†IQR, interquartile range; *TST, total sleep time.

4.1. Telemonitoring and recording quality

A TM system allowing remote viewing of the sleep recordings was used in this study. TM may decrease the failure rate of unattended PSG [21,22] and enhance the possibility of performing sleep studies outside of the sleep laboratory. In the present study, a TM system (Sleepbox "□") was used to monitor the sleep studies performed in the CCU. Although the sleep test was unattended for six patients due to 3G-network connection problems, all PSG recordings were of excellent quality. Interventions were required in 10 patients to successfully resolve sensor loss. The success rate for our recordings was 100%, similar to that of attended sleep studies.

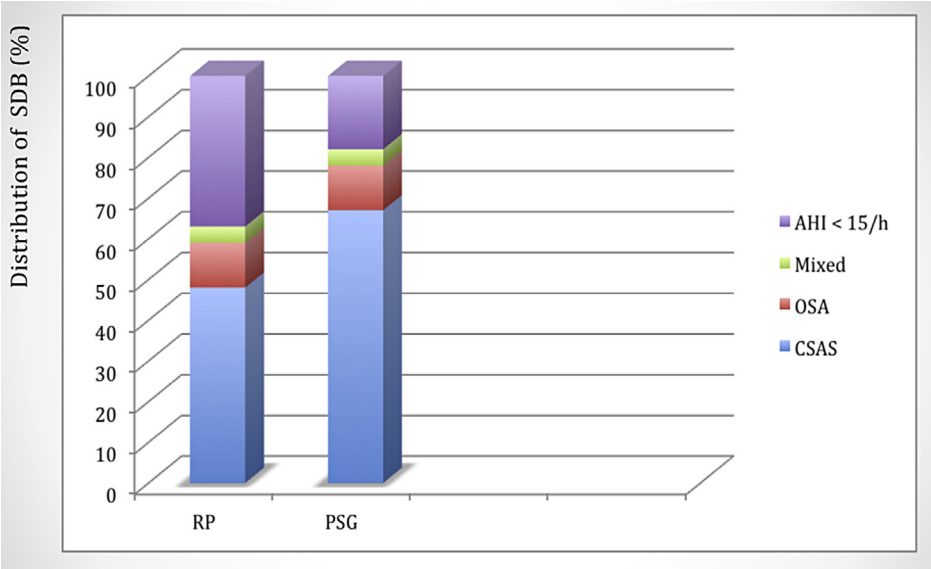

Fig. 3. Difference in the distribution of the sleep-disordered breathing (SDB) obtained with polysomnography (PSG) and respiratory polygraphy (RP). This scheme represents the proportion of patients with an apnea–hypopnea index (AHI) ≥ 15/h, and the type of SDB observed. Compared to PSG, RP tended to underestimate the proportion of central sleep apnea syndrome (CSAS) and periodic breathing patients, whereas PSG and RP yielded similar results in obstructive sleep apnea syndrome (OSA) patients.

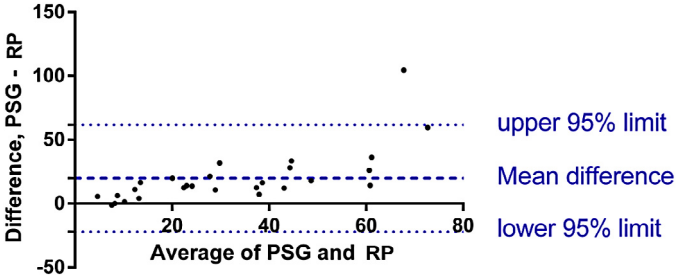

Fig. 4. Bland–Altman analysis. The Bland–Altman plot of the difference in apnea–hypopnea index (AHI) between polysomnography and respiratory polygraphy (PSG minus RP), expressed in absolute units; as a function of the average between PSG-AHI and RP-AHI. We obtained a bias (mean difference) of 19.85 (standard deviation, 21.38) for the AHI with a two-sided 95% confidence interval [−22.06 to 61.76]. This suggests that RP underestimates the AHI with a bias of almost 20 compared to PSG.

4.2. Polysomnographic results

Spending a long time in bed, predominantly in the supine position, was observed in these acute admission patients to whom permanent bed rest was recommended by the cardiologist. Long sleep latency was observed, but was probably overestimated, as sleep onset based on light-on/light-off time could not be determined. Sleep architecture was severely disturbed with a high arousal index and poor SE. This sleep disruption was multifactorial (noise, monitoring of vital parameters every 2 h at night, acute stress due to hospitalization, first night effect, ACS, SDB) and could have contributed to qualitative and quantitative sleep deprivation, which can have a negative impact on the course of ACS [23]. Our observations on sleep alterations (reduction of SWS and REM) and light–dark cycle disturbances are in agreement with previous data described in CCU patients [23,24]. However, unlike intensive care units, in which sleep quality is always altered [25], a small proportion of our patients conserved satisfactory sleep architecture with acceptable sleep quality (15% patients with SE ≥ 70%), which can be explained by the quieter environment (single room) in the CCU compared to intensive care units.

4.3. Comparison between polysomnography and respiratory polygraphy

The current reference method for the diagnosis of SDB is still attended PSG, performed in a sleep laboratory [26], which allows complete evaluation of the sleep (neurologic, cardiorespiratory, etc.) and diagnosis of other sleep disorders (periodic leg movement syndrome, epilepsy, cardiac arrhythmias). Today, indications for the use of portable monitoring such as RP are limited and not suitable as an SDB-screening tool in an asymptomatic population [27], which was the situation that we faced in this study. Even if RP offers practical, technical advantages and can confirm SDB in high-risk patients, all negative recordings require a confirmation by PSG due to its low negative predictive value [28]. The absence of the correct sleep time evaluation makes it inappropriate for the diagnosis of SDB, especially in CSAS and CSR where we know that patients exhibit altered sleep architecture associated with repeated arousals. Accordingly, it partially explains the higher prevalence of SDB observed with PSG than with RP in our patients suffering from poor sleep [29]. Indeed, the Bland–Altman analysis showed that RP underestimated the AHI with a bias of almost 20 compared to PSG. These values tended to be more disseminated for higher AHI values. A fairly large confidence interval was observed for the bias due to the small sample size, and these results must therefore be interpreted cautiously. However, this bias is clinically significant such that it has a clear impact on the clinical management. These observations may encourage the use of PSG rather than RP in the specific ACS population screened for SDB and with marked sleep disruption.

4.4. Obstructive sleep apneas

We decided to set up a treatment with CPAP for our three patients diagnosed with OSA, during the acute phase, knowing that this therapy can prevent the risk of a new coronary event after ACS [5]. Furthermore, all our obstructive patients presented with severe disease – an additional reason to introduce as soon as possible a potentially non-invasive "life-saving" therapy, even in asymptomatic patients. As expected, six months after the ACS, the reassessment by PSG revealed a regression of OSA, even if treatment with CPAP remained indicated.

4.5. Central sleep apneas

This study demonstrated a higher prevalence of SDB than did previous studies [7,8] and, surprisingly, despite a majority of patients with preserved cardiac function (89%), a clear predominance of severe CSAS and PB. These results are in contrast with previous reports showing a higher proportion of OSA. However, these studies, based on heterogeneous populations (ACS, stable/unstable angina, HF), were conducted in various settings (CCU, cardiology ward, home, sleep laboratory) and were performed with either PSG or RP, with variable AHI thresholds (from 5 to 15/h). These studies focused on obstructive events and none of them reported the presence or high prevalence of CSAS [3,6,7,30–33]. On the contrary, studies including patients with impaired cardiac function demonstrated a marked predominance of CSAS [34]. Our study avoids many of the biases observed in previous studies: the population was homogeneous as only consecutive ACS patients without acute HF were included. None of the patients suffered from comorbidities known to increase the prevalence of SDB (opioid use, chronic obstructive pulmonary disease, stroke). The threshold chosen for SDB was AHI ≥ 15/h, corresponding to a threshold above which the mortality of HF patients is increased [16].

We hypothesize that, immediately after the acute cardiac event, patients are at risk of ventilatory instability. The cardiac function of our patients was preserved apart from three subjects with LVEF of 30% but no signs of acute HF. These three patients suffered from severe CSAS (AHI ≥ 48/h) with permanent PB, confirming that cardiac dysfunction leads to ventilatory instability [19,35]. Furthermore, after coronary angiography, patients received physiological saline infusion for the next 48 h to prevent iodinated contrast-induced acute kidney injury. Possible short-term fluid overload may have impaired cardiac performance and may also have played a role in ventilatory instability during the very early phase of ACS [36,37]. Another potential underlying mechanism that could explain the high prevalence of CSAS observed is the "wake/sleep transition" phenomenon. Indeed, the wake/sleep or sleep/wake transition is a period characterized by unstable respiratory control, in which the propensity to develop central sleep apneas increases, even in healthy subjects [38]. So, in highly fragmented sleep, the repetition of arousals could have played a role in the occurrence of CSAS, even if central events occurred not only after arousals, but also in stable sleep stages.

Moreover, it is well known that CSAS and PB occur more frequently during NREM sleep and tend to disappear in REM sleep. During NREM sleep, ventilation is under metabolic control and is closely linked to the changes in $PaCO_2$. On the contrary, REM sleep is characterized by behavioral control of ventilation insensitive to $PaCO_2$ changes, and by a decrease in the respiratory drive, explaining the less frequent occurrence of CSAS and PB [17]. Could the lack of REM sleep in our population have an impact on the high prevalence of CSAS and PB observed?

Finally, the early recording can partly explain the differences between our results and those of previous studies.

Only few CSAS patients were re-evaluated aloof from ACS, as the follow-up was not mandatory in this study. Indeed, even if we observed a tendency to CSAS regression, the majority of CSAS patients who clinically improved after the ACS did not intend to perform the reassessment. This could constitute a bias, as re-evaluation might have been centered only on unstable patients.

4.6. Clinical implications of sleep-disordered breathing occurrence during the early phase of acute coronary syndrome

Repetitive apneas (central or obstructive) induce arousals and intermittent hypoxia that have negative impacts on the cardiovascular system: increase in blood pressure and heart rate, depression of myocardial contractility, activation of the sympathetic nervous system, and raising of the cardiac workload. These deleterious effects could lead to infarct expansion or inhibition of left function recovery after ACS [30]. Previous studies have demonstrated that OSA treatment reduces the occurrence of new cardiovascular events [5] and significantly reduces cardiac death in ACS patients after percutaneous coronary intervention [10]. However, controversy persists about whether CSAS and PB are a reflection of the cardiac disability or whether they have a prognostic impact. Small studies suggested an increased cardiovascular mortality [39], notably in HF patients with CSAS and PB [17]. Accordingly, early detection of SDB could lead to more intense medical management of SDB during the early phase of ACS to avoid immediate and additional cardiac workload alteration. It remains to be determined in larger studies whether such therapeutic strategies could reduce ACS mortality.

4.7. Sleep-disordered breathing screening at the early phase of acute coronary syndrome

There remain unresolved questions about opportunity and timing of SDB screening during the early phase of an ACS. If the screening is very precocious, it can lead to overdiagnosis since prevalence and severity of OSA may decrease over time [7,8,40]. Moreover, we may have recorded ventilatory instability due to the acute condition and we do not know its clinical impact. On the other hand, rapid SDB management could be efficient to improve cardiac function [41]. We believe that it is more appropriate to screen patients when they are still in the hospital wards. We have to keep in mind the possible regression of SDB over time. Therefore, reassessment of SDB was performed in some patients by RP or PSG, but was not systematic, as follow-up was not initially included in the study protocol. In these recordings, a high proportion of persistent SDB was observed. Based on these unexpected results, we think that systematic re-evaluation of SDB should be proposed for this population to diagnose persistent troubles.

4.8. Limitations

This study presents several limitations, including the relatively small number of patients, as this pilot study was designed to evaluate the feasibility of SDB screening outside of the sleep laboratory. Our results concerning comparison of PSG and RP for SDB screening in ACS patients therefore cannot be generalized and the underlying pathophysiological mechanism leading to CSAS and PB cannot be explained. Measurement of arterial blood gases ($PaCO_2$ level), pro-brain natriuretic peptide, and evaluation of diastolic function would have been useful to assess CSAS and PB. However, these examinations are not performed routinely. Although TM has enabled excellent quality recordings, some technical improvements are required to allow sleep studies to be performed outside the sleep laboratory in the future.

5. Conclusions

This pilot study shows that early SDB screening by PSG is feasible in ACS patients shortly after admission to a CCU. The use of TM allows remote-attended PSG in particular settings (CCU) and, despite a few technical problems, the quality of sleep studies was enhanced. These results indicate the presence of disrupted sleep and a high prevalence of central SDB, the etiology for which remains unknown. Further large-scale studies are needed to determine whether central SDB in early ACS is an incidental finding and whether the presence and severity of SDB have a prognostic impact.

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Conflicts of interest

The ICMJE Uniform Disclosure Form for Potential Conflicts of Interest associated with this article can be viewed by clicking on the following link: http://dx.doi.org/10.1016/j.sleep.2014.06.017.

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